ARL / ARO
Terrestrial Sciences
Basic Research Program

Briefing to:

JLOTS and Logistics from the Sea R&D Symposium
on
Army Coastal Environment Basic Research

By

Dr. Russell S. Harmon
U.S. Army Research Office
tel: 919-549-4326   fax: 919-549-4310
e-mail: harmon@aro.arl.army.mil

29 January 2002

OVERVIEW

- **ARO**
- **The ARO Terrestrial Sciences Program**
- **Current Coastal Basic Research**
- **Future Research Directions**

Army S&T Organizati on

HQ DA

Operators

User Rep (TRADOC)

ASAAL

PEOs

Materiel

HQ AMC

Medical

HQ MRMC

Infrastructure/ Environmental

HQ USACE

Personnel

DCSPER

Strategic Defense

SMDC

Army Research Laborato

Aviation and Missile Command
AMCOM
Missile RDEC
Aviation RDEC

Soldier & Biological Chemical Command
SBCCOM
Edgewood Chem-Biological Center
Natick Soldier Cntr

Communications - Electronics Command
CECOM
Communications & Electronics RDEC

Tank-Automotive & Armaments Command
TACOM
Tank-Automotive RDEC
Armament RDEC

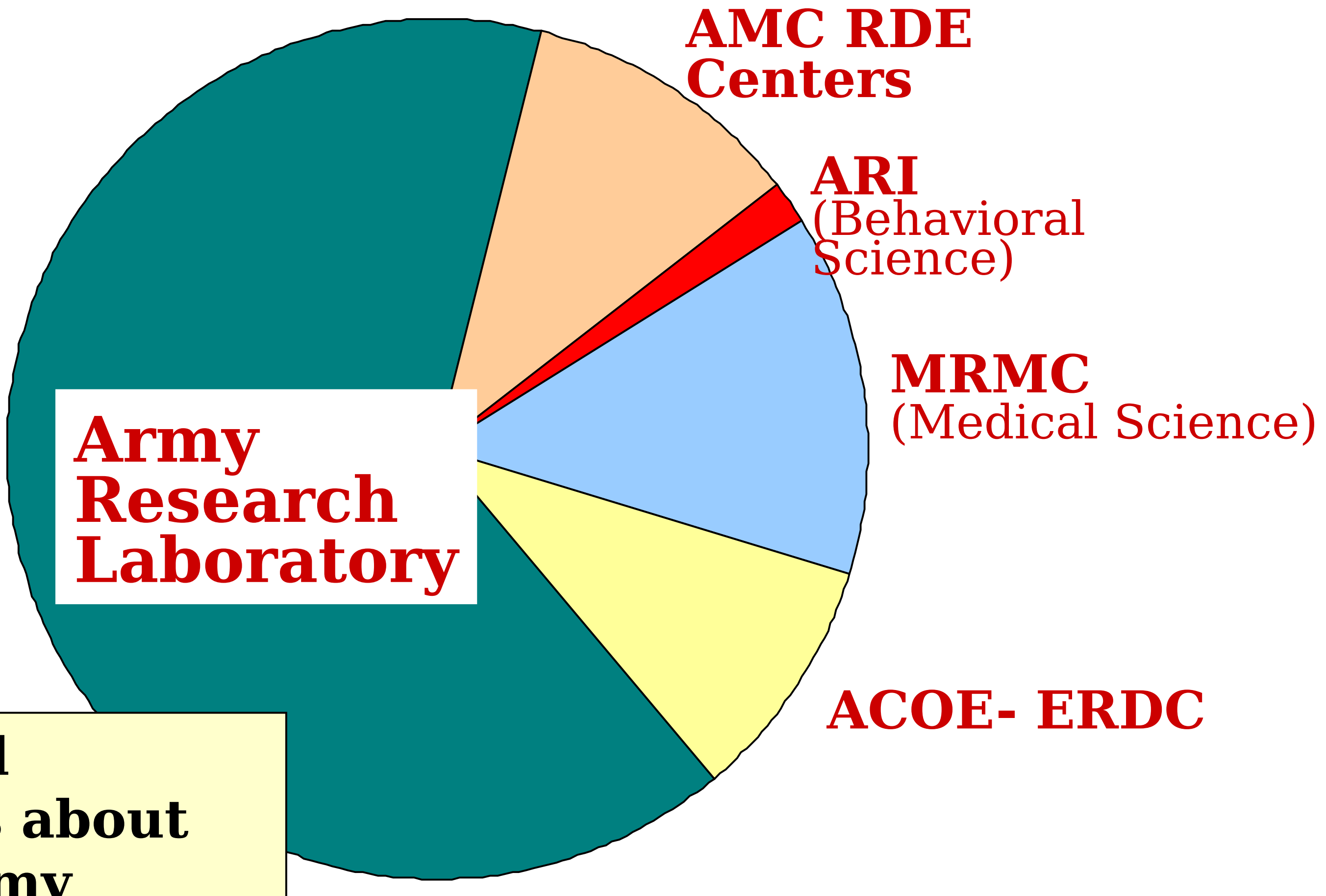
Operations Support Command
OSC

Simulation, Training & Instrumentation Command

U.S. Army Security Assistance Command
USASAC

Army Basic Research Resource Allocation

$205 Million FY01



Army Materiel Command has about 70% of the Army Basic Research Budget

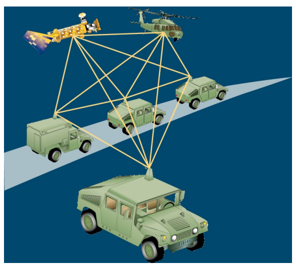
Army Research Laboratory
Organizational Structure

Director

- Deputy Director
- Dep. Director for Research
- Associate Dir. for PP&B

Army Research Office

- European Research Office
- Far East Research Office



Computational & Information Sciences Directorate

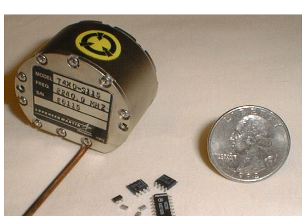
Vehicle Technology Directorate

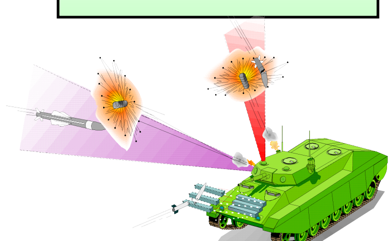
Sensors & Electron Devices Directorate

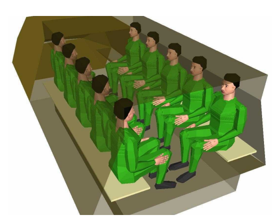
Weapons & Materials Research Directorate

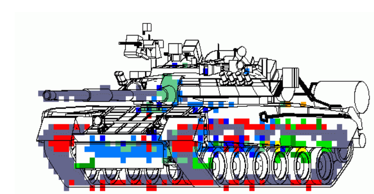
Human Research & Engineering Directorate

Survivability/ Lethality Analysis Directorate

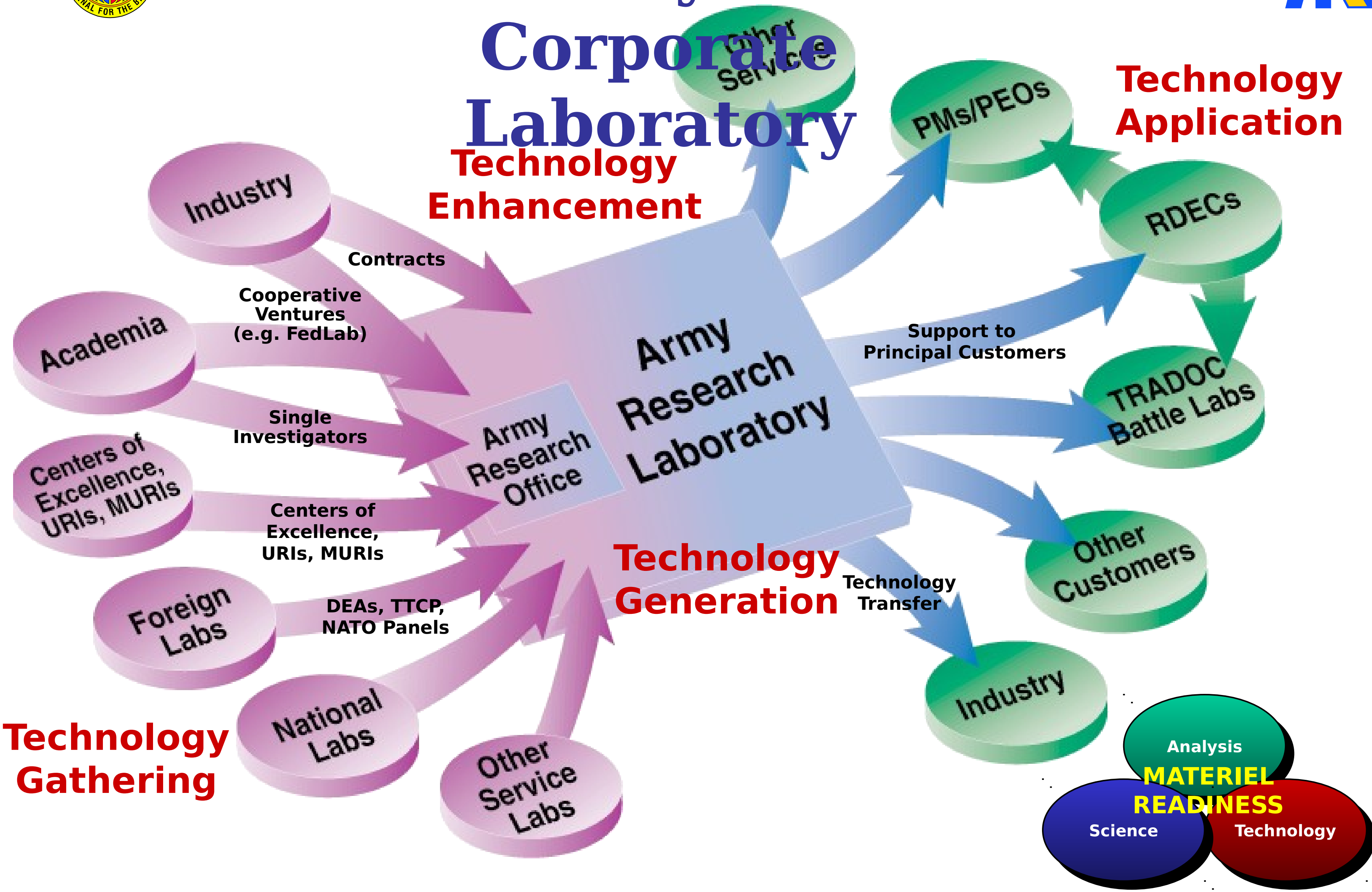








The Role of the Army's Corporate Laboratory



The Army Research Office (ARO)

Seeding Army Research at over 300 Academic Institutions

Managing ACT II and SBIR to Transfer Technology to the Army User

Assessing Scientific Opportunities to Achieve Army Vision

Manage ARL-ERO and ARO-FE International Offices

Strengthening the research infrastructure at HBCU/MIs

Educating a Superior Workforce in Army-Critical Technologies

With…

- An Army Investment of $58M

and…

- A Workforce of 99 Highly Educated and Motivated Staff

ARO…

Focuses a Total 6.1 Program of $166M from all Sources plus $ from SBIR and ACT II in Support of Army Technology Objectives

ARO heavily leverages the resources of other agencies to support the Army mission

ARO Basic Research Pursuits

Communications & Information Processing Research
- Information fusion
- Wireless distributed communications
- MMW integrated devices

Mathematical Sciences
- Knowledge-based systems
- Intelligent systems
- Complex systems and control

Biological Sciences
- Microbiology & Biodegradation
- Physiology & Performance
- Nanoscale biomechanics

Chemical Sciences
- Electrochemistry
- Fast, energetic materials
- Dendritic polymers

- **Portable power**
- **Low power**
- **Intelligent**
- **Microsized**
- **Multifunctional**
- **Autonomous**
- **Lightweight**
- **Logistics ease**

Physics
- Image analysis
- Nanoscience
- Photonics

Mechanical Sciences
- "Smart" structures
- Rotorcraft aeromechanics
- Combustion/Propulsion

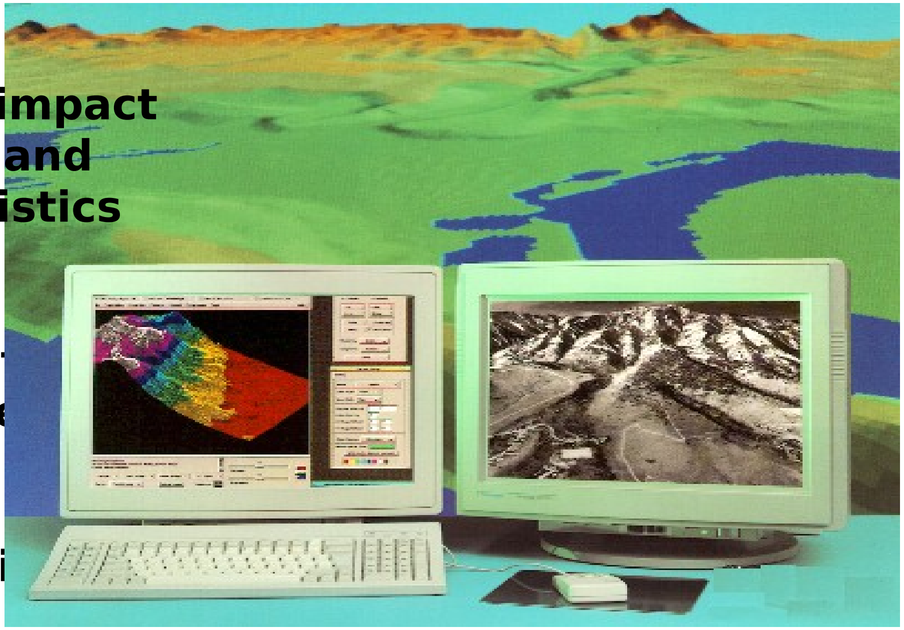
Materials Science
- Biomimetics
- Hierarchical materials
- Smart materials

Atmospheric and Terrestrial Sciences
- Atmospheric lower boundary layer
- Remote sensing/terrain & topography
- Surficial Processes
- Environmental modeling

Electronics
- Low power/noise electronics
- Optoelectronic hybrids
- Quantum & High Frequency Electronics

ARO - TERRESTRIAL SCIENCES

THE GRAND CHALLENGE



Terrain and the terrestrial environment impact Army training and testing; the planning and execution of military operations and logistics activities.

The probable Army battlespace for the fu will be extended, highly complex, variable and dynamic.

Under such conditions, effective warfighti will require:

- **Superior terrain knowledge and battlespace visualization capabilities**
- **Fundamental understanding of (i) terrain character, (ii) dynamic constitutive behavior of natural and engineered materials, and (iii) terrestrial processes under different environmental conditions, that is needed to develop new modeling and simulation capabilities that will enable the Army to foresee and exploit terrain and environmental**

ARO - TERRESTRIAL SCIENCES

MAJOR PROGRAM AREAS

(from Jan '01 Environmental Sciences Triennial Strategy Planning Meeting)

- **Terrain Properties and Characterization**
  - → The natural and human-affected landscape
  - → The subsurface environment

- **Terrestrial Processes and Dynamics**
  - → Physical and ecological processes
  - → Hydrologic and geomorphic processes
  - → Geomechanics and constitutive relations
  - → Extreme environments

- **Terrestrial System Modeling and Analysis**
  - → Vehicle-terrain interaction
  - → Geophysical modeling
  - → Landscape impact response and sustainability
  - → Geospatial and environmental model development

ARO - TERRESTRIAL SCIENCE

TERRAIN PROPERTIES & CHARACTERIZATION

AREAS OF INTEREST

- Terrain information generation, characterization, and analysis
- Battlefield visualization and environmental simulation
- Subsurface characterization

OBJECTIVES

- Provide a foundation for the development of new terrain characterization and feature extraction and analysis capabilities
- Undertake field and laboratory studies to obtain the fundamental material properties data necessary for the development of physical process models
- Development of novel environmental site characterization technology utilizing the SBIR/STTR program

PAYOFF

- Improved terrain extraction, characterizati and analysis capabilities for battlespace visualization, multi-resolution geospatial reasoning tools, and robotics applications
- Realistic, dynamic synthetic virtual simula environments for training and mission rehe
- New capabilities for the in-situ determinat of subsurface character and toxic substanc in the environment

ARO - TERRESTRIAL SCIENCE

TERRESTRIAL PROCESSES & DYNAMICS

AREAS OF INTEREST

- Physical and ecological processes
- Hydrologic and geomorphic processe
- Nearshore processes
- Geomechanics and constitutive relat
- Extreme Environments

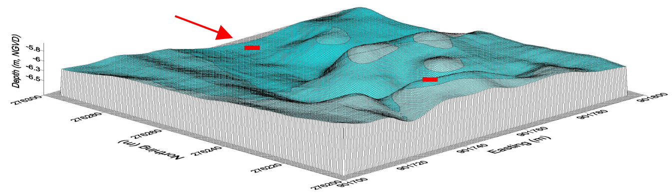
OBJECTIVES

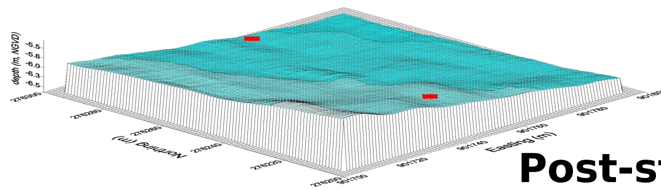
- Undertake field and laboratory studies to understand surface processes in different environments that affect military operations at a fundamental level
- Development and validation of dynamic, multi-scale physical process algorithms and numerical models

August 26, 1999

Pre-storm Shoreface
- transverse bars
- troughs with mud surfa

core locations





Post-storm Shoreface
- planar surface
- no mud at surface

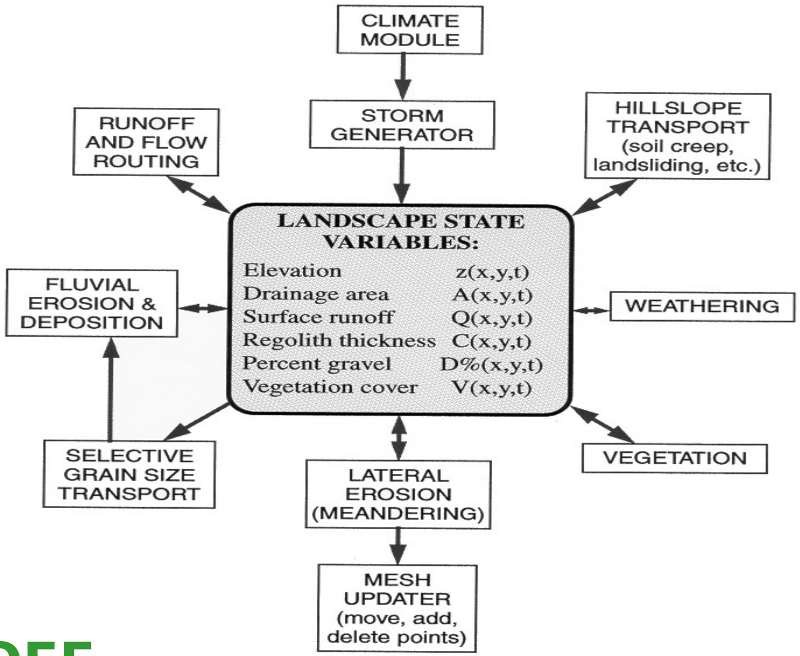
September 29, 1999

PAYOFF

- Improved process models and terrain realis for interactive simulation in the virtual world
- New and enhanced physical process models for environmental forecasting and prediction (e.g. “real-time” hydrologic and coastal dyna forecasting, mobility prediction, and contami transport and remediation efficacy modeling)

ARO - TERRESTRIAL SCIENCES

TERRESTRIAL SYSTEM MODELING & ANALYSIS



AREAS OF INTEREST

- Vehicle-terrain interaction
- Geophysical modeling
- Landscape impact response and sustainabili
- Geospatial and environmental model develo

OBJECTIVES

- Integration of terrain character, material property information, and surficial process process and landscape dynamics models into new /enhanced environmental simulators for Army applications
- Field and laboratory and field studies for model validation

PAYOFF

- Improved capabilities for:
  - → the Army COE*SYNTHERM* cold climate mod
  - → the Army *Engineer Obstacle Planning Syste*
  - → the Army COE *Watershed Model System*
  - → the NATO Reference Mobility Model
  - → the DOD *Groundwater Model System*
  - → the Army COE *Land Management System*

ARO - TERRESTRIAL SCIENCES

NEARSHORE PROCESSES RESEARCH AREAS

- Dynamic variability of coastal geomorphology and nearsho sediment transport
- Wind-generated surface waves
- Coastal circulation
- Water-level and water property variations
- Research models to treat individual and coupled aspects o and substrate character (composition and topography), wa currents, and water levels

ARO - TERRESTRIAL SCIENCES

RECENT & CURRENT NEARSHORE BASIC RESEAR

- Bottom Topography in the Nearshore Environment (J. McNinch - ARO NRC Fe
- Field and Modeling Studies of Nearshore Morphology (T. Drake - North Carol
- Boussinesq Modeling of Waves in Harbors and Tidal Waves (J. Kirby - U Dela
- Multisensor Approach to Mapping of 2-D and 3-D Geologic Features from Re
  Sensed Imagery (M. Crawford - U Texas)
- Onshore Sand Bar Migration (S. Elgar - Woods Hole Oceanographic Institut
- A Computational Model for the Hydrodynamics and Littoral Processes at the
  Scale Sediment Transport Facility at WES (I. Svendsen - U Delaware)
- Multi-Scale Characterization and Simulation of the Nearshore Environment
  Open Source GIS Technology (H. Mitasova - ARO NRC Fellow at North Carol

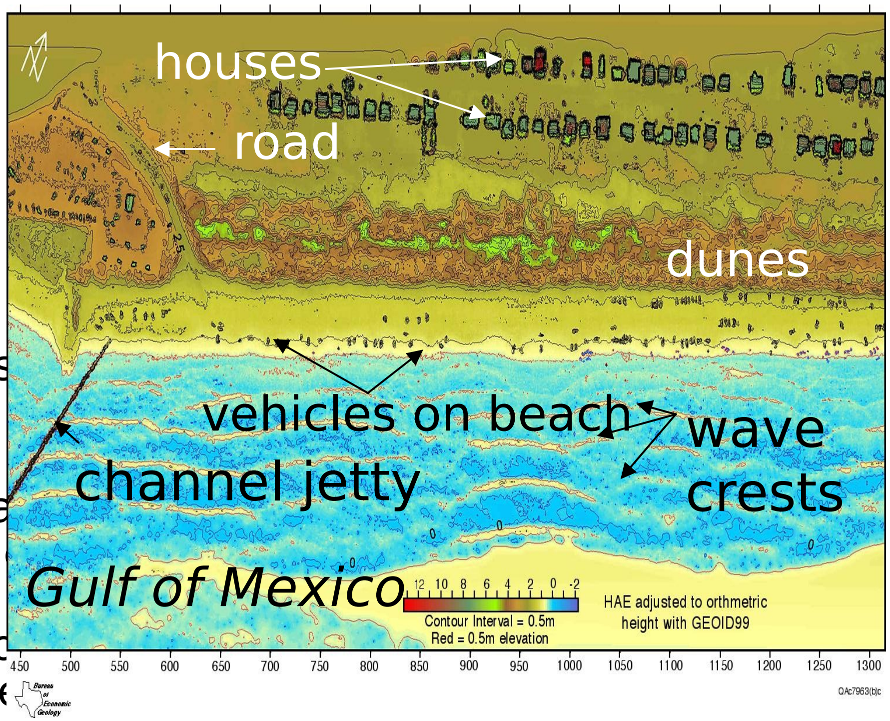
Characterizing the Beach Zone via Airborne Lidar

PERFORMER:

- Dr. Melba Crawford, U Texas (cooperative with ONR)

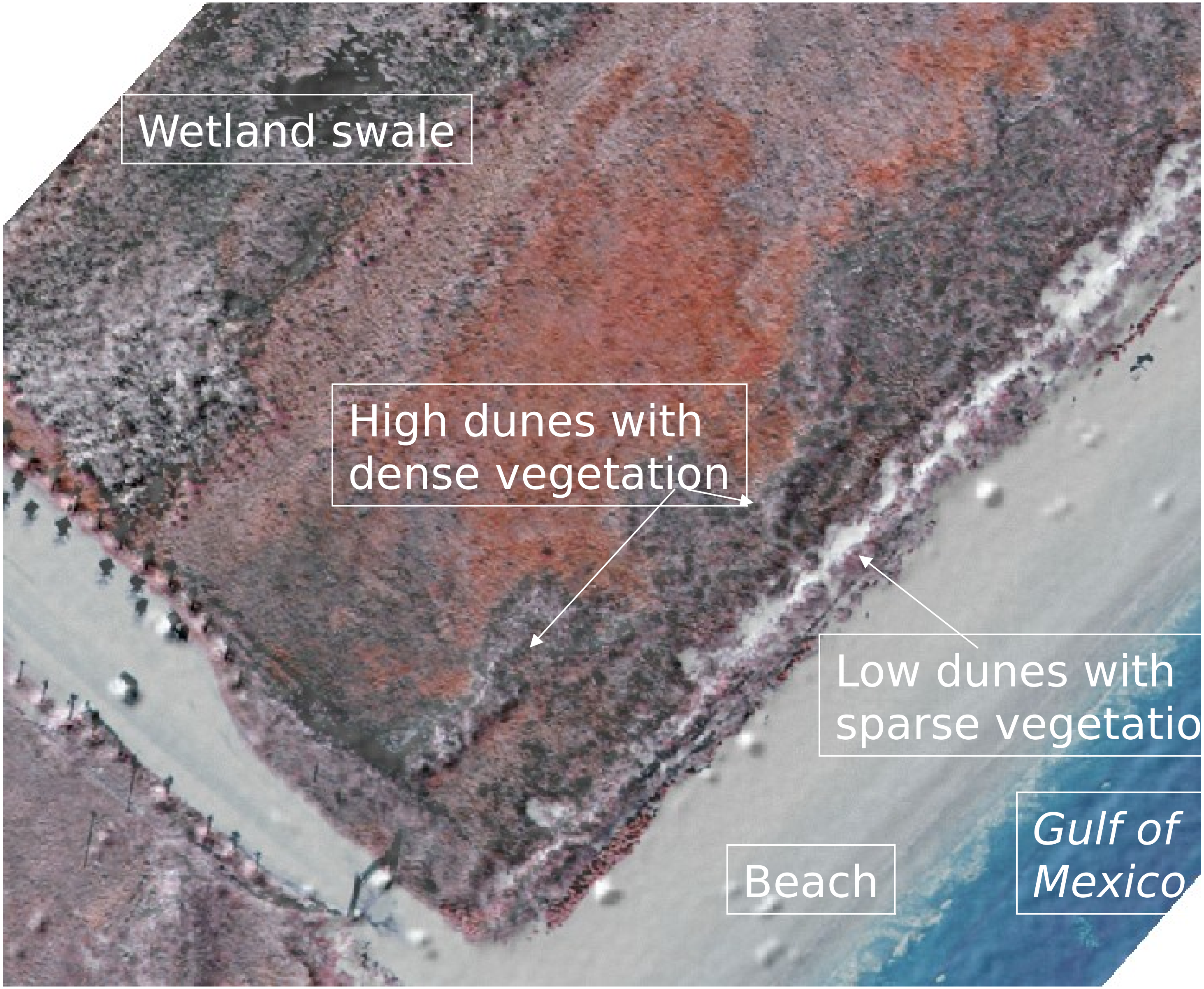
OBJECTIVES:

- Characterize the beach, dune, and wetland environments of barrier islands using airborne Lidar
  - → Acquire and analyze airborne Lidar da over the barrier island environments the Texas coast
  - → Develop algorithms and techniques fo Lidar processing, filtering, and feature mapping
  - → Develop applications for characterizing barrier island geomorphology and sedimentary environments
  - → Develop automated algorithms for detecting and quantifying change from multiple Lidar surveys

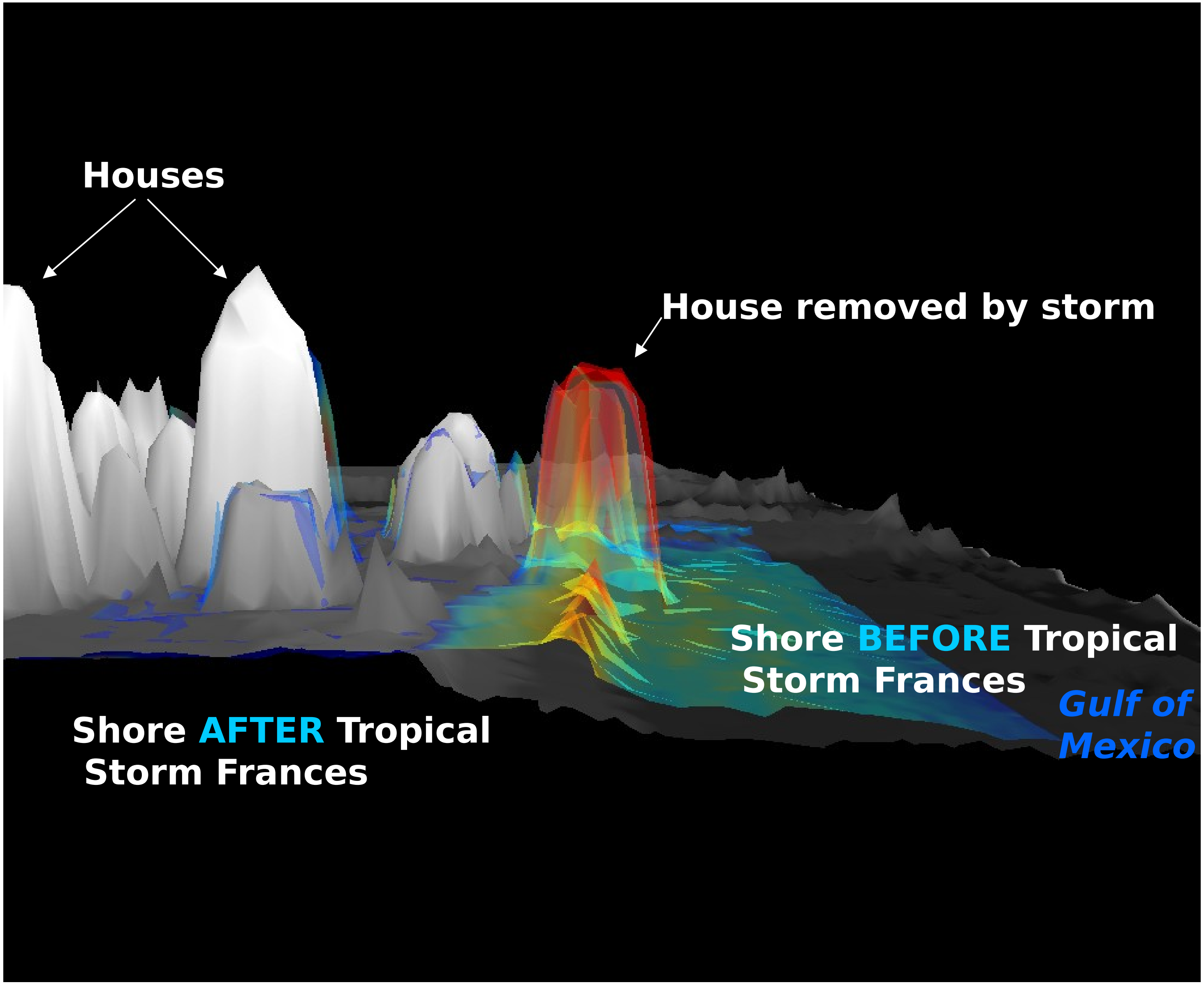


APPROACH:

- Analyze existing beach/dune Lidar data acquir along the Texas Gulf of Mexico shoreline
- Acquire new Lidar data that includes back barrier environments
- Build on earlier UT Lidar classification research and apply to barrier island environments
- Evaluate results of algorithms and applications using



Color IR draped on Lidar Topography



Topographic Change from Lidar

Field and Modeling Studies of Nearshore Morphology

PERFORMER:

- Dr. Tom Drake - North Carolina State U (cooperative with USACE-FRF)

OBJECTIVES:

- To understand and predict the evolution of surf-zon and shallow-water bathymetry and sedimentation
  - → relate evolution of nearshore bottom morphology to fluid-motion measurements and to determine which, if any, morhological features can be used as surrogate sensors of fluid motion
  - → To describe and quantitatively model, for the first time, the sediment transport processes that occur in the nearshore environment

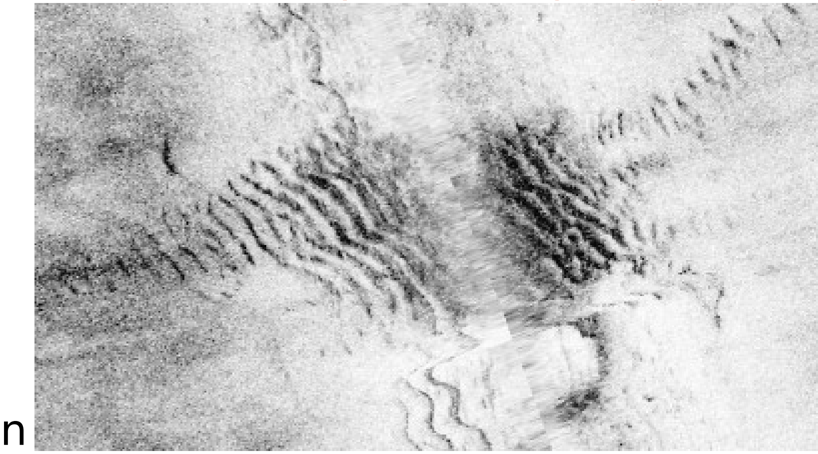
APPROACH:

- Field studies: repeated mapping of the swash zone at the USCAE FRFat Duck, NC to -15m depth
- Model studies: computer modeling of bathymetric evolution over sub-meter to kilometer length

COE-FRF amphibious vehicle for side-scan radar imaging

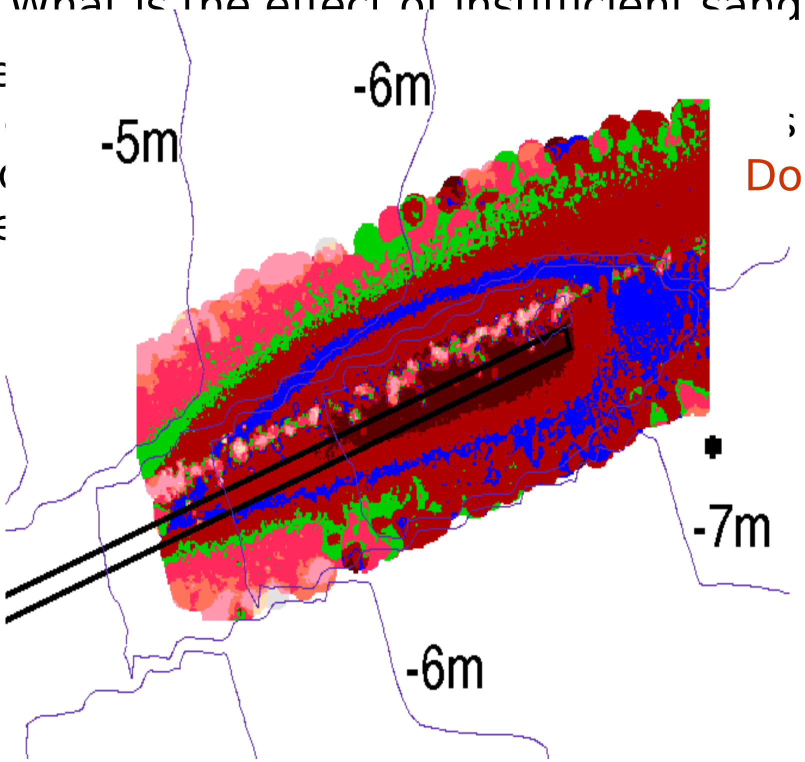
COE-FRF “CRAB” for small-scale bathymetric mapping

Isolated 1m-Spaced Megaripples at D



QUESTIONS:

- What nearshore bed features evolve rapidly during storms?
- Can such changes be rapidly and remotely assessed?
- What is the effect of insufficient sand supply on the g... and other be... fe...



"CRAB" profile mapping vs high-resolution swath bathymetry (10cm vertical resolution) showing deep (>8m) scour holes under FRF pier

Do patches indicate:

→ Underlying geology?

→ Current and wave patterns?

→ Grain-size control of bedforms?

ACCOMPLISHMENTS:

- Conducted high-resolution mapping of nearshore bottom topography
- Developed a cell-based numerical mode sand transport under waves and currents the nearshore and coastal environments
- Assimilated bathymetric data into a cel automata models for bottom topography morphologic evolution

Onshore Sand Bar Migration

PERFORMER:

- Dr. Steve Elgar
  (Woods Hole Oceanographic Institute)

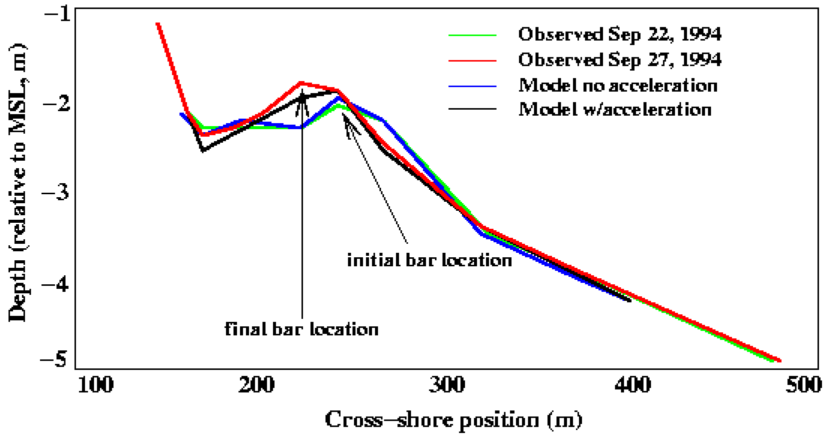
OBJECTIVES:

- To determine the mechanisms of of nearshore sediment transport in order to develop models the predict the evolution of sandbar-scale topography in response to forcing by waves and currents

APPROACH:

- Incorporation of sediment transport monitoring data in the mixed wave zone of the nearshore and surf zone into state-of-the-art numerical models to predict the evolution of beach topography

Model Prediction of Onshore Sandbar Migration Observed at the US Army Corp of Engineers Field Research Facility



The sand bar moved from cross−shore position = 275 m (green) to position = 225 m (red) in 5 days. The numerical model with acceleration terms (black) accurately predicts the observed change in beach topography.

- Sandbar movement causes:
  - → large changes in topography
  - → object burial and exposure
  - → changes in breaker location

Bottom Topography in the Nearshore Environment

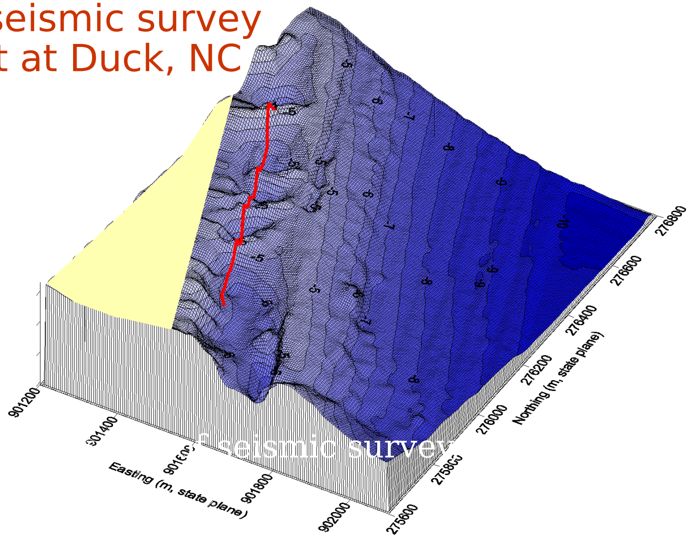
PERFORMER:

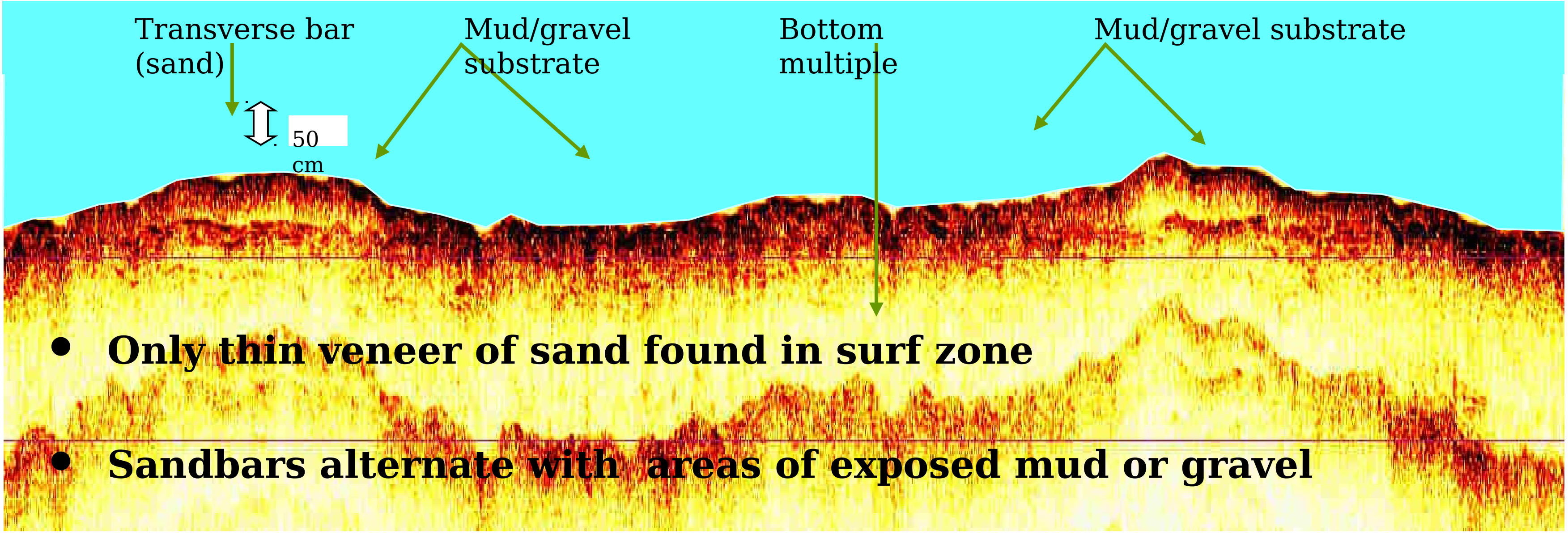
- Dr. Jesse McNinch - ARO NRC Post-Doctoral Fellow resident at USACE-FRF (collaborative with Dr. T. Drake, NCSU)

APPROACH:

- Field studies: repeated mapping of the swash zone at USCAE FRF at Duck, NC to -15m depth
- Model studies: computer modeling of bathymetr evolution at different length scales

Trackline of seismic survey along coast at Duck, NC



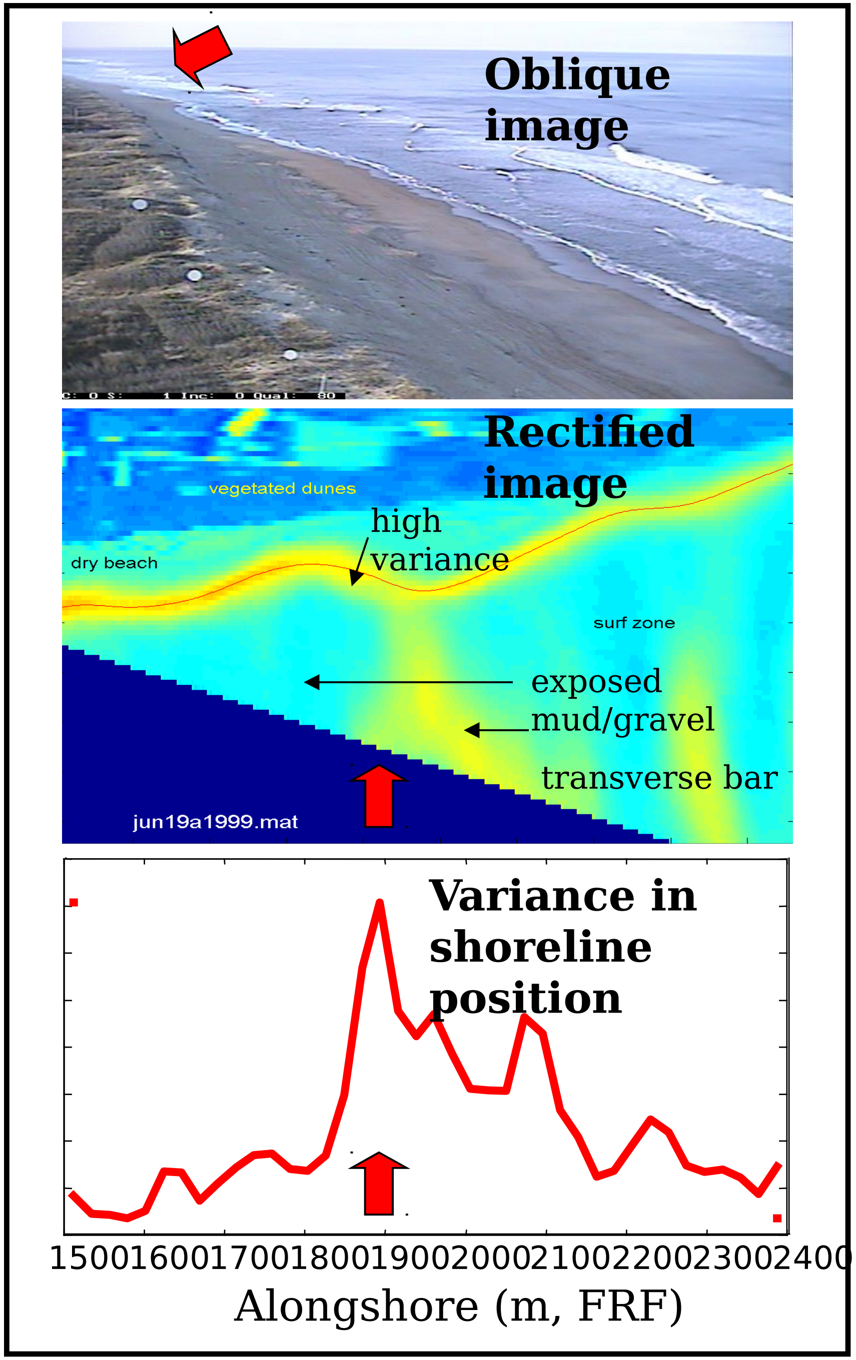


- **Only thin veneer of sand found in surf zone**
- **Sandbars alternate with areas of exposed mud or gravel**

- Beaches that experience rapid and repeated cycles of erosion and accretion are linked to the presence of:

→ exposed non-sandy sediment

→ transverse bars

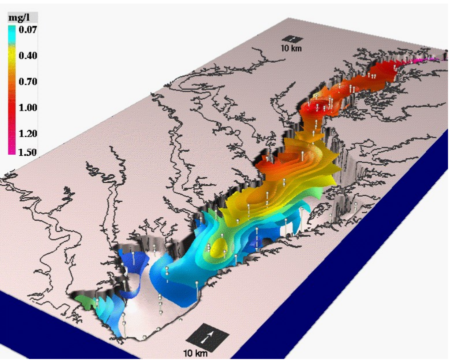


focus on the globe ~ earth system sciences
MEAS
Marine, Earth & Atmospheric Sciences
North Carolina State University

Multi-Scale Characterization and Simulation of the Nearshore Environment

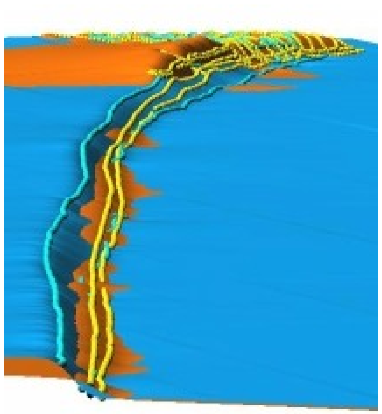
PERFORMER:

- Dr. Helena Mitasova - ARO NRC Post- Doctoral Fellow resident at (collaborative with Dr. T. Drake, NCSU)



OBJECTIVE:

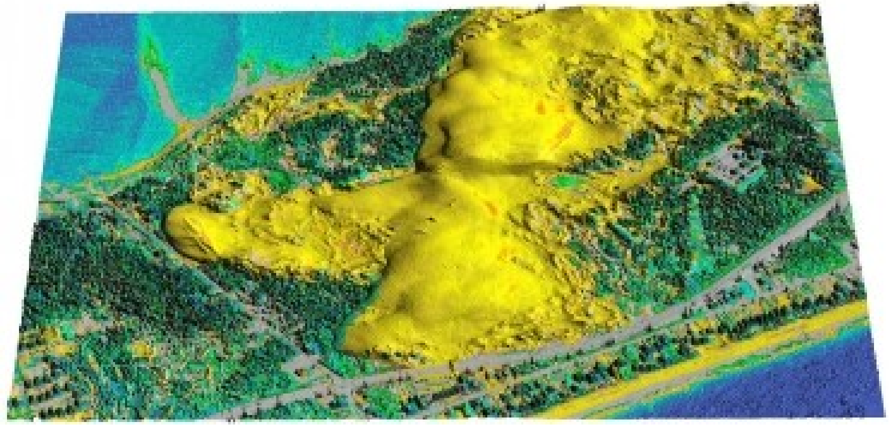
Coastal field measurements and models involve processing, analysis and visualization of large volumes of georeferenced data, often in different computational environments and formats. To fully support coastal research and management GIS needs to be enhanced to provide better support for working with large, heterogeneous, spatio-temporal data sets at multiple scales.



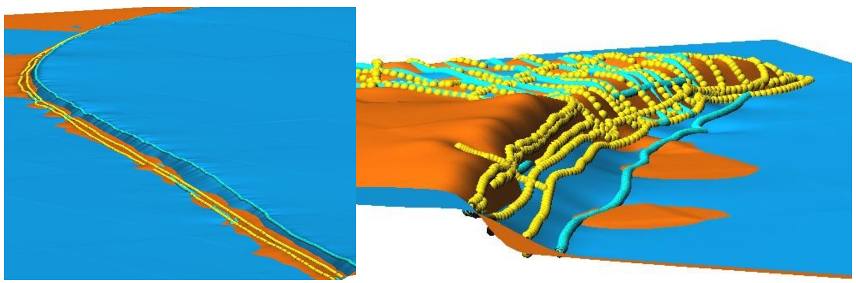
APPROACH:

Enhance and develop methods and tools for Open source GIS GRASS in the following areas:

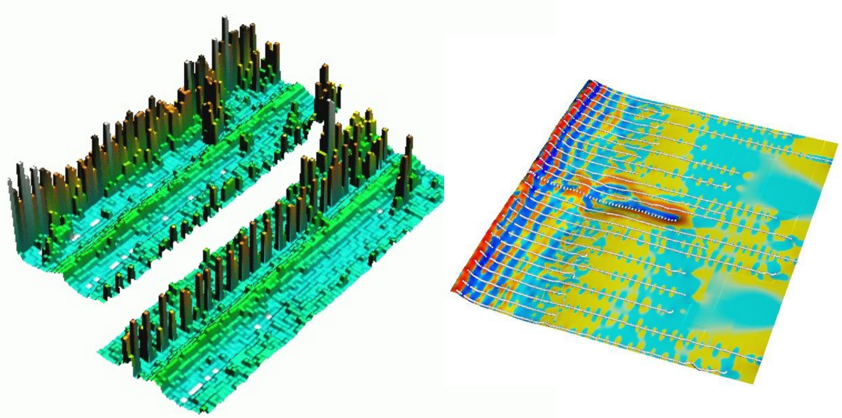
- multivariate interpolation with simultaneous geometrical analysis of near-shore sedimentary structures and geomorphology
- dynamic cartography for visualization of measured data, interpolated surfaces and volumes as well as results of simulations



ockey’s Ridge LIDAR-based DEM with IR-DOQQ
(Data NOAA/USGS)



Bald Head Island shoreline (Data T. Drake, D.Bernstein)



Duck: rasterized sonar data , interpolated LARC data: profile curvature (Data FRF Duck, T.Drake)

ACCOMPLISHMENTS:

RST method with simultaneous topographic analysis was applied to several types of data used for characterization of nearshore environment:

- **LIDAR: Jockey's Ridge was interpolated at 1m resolution with analysis of surface geometry at various levels of detail. Improvements of performance for high density data points is being implemented. The 3D view of Jockey's Ridge with draped IR-DOQQ was created using GRASS GIS tool NVIZ.**
- **LARC and RTK GPS measurements were interpolated to evaluate the RST capabilities to generate surfaces from profile data with directional over-sampling. The anisotropy is being implemented to preserve the maximum detail in the profile data. The shorelin a from December (orange) and January) were visualized in NVIZ to assess the eroding shoreline**

TECHNOLOGY TRANSFER: →

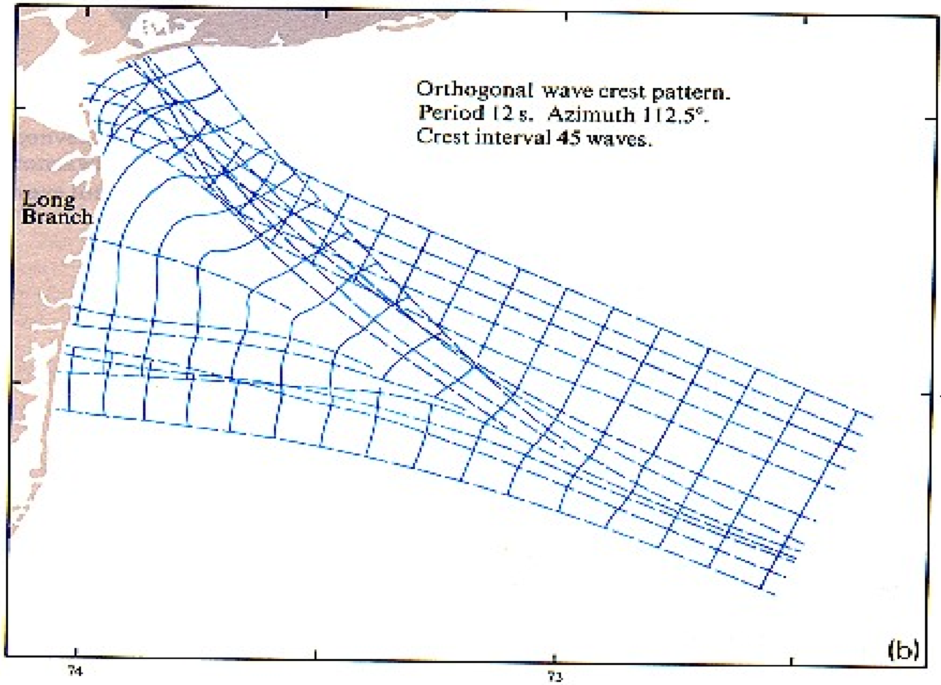
- **Jockey’s Ridge LIDAR was included in the book on Open source GIS: the GRASS GIS approach, to be published in 2002.**
- **Once improvements are tested, they are immediately released into the developmental**

Boussinesq Modeling of Waves in Harbors and Inlets

PERFORMER:

- Prof. James Kirby - U Delaware

Refraction of waves off Long Branch beach due to the Hudson Canyon



OBJECTIVE:

- Develop a nearshore water and wave model using generalized coordinates in the horizontal plane, to extend Boussinesq model calculations to complex, irregular coastal geometries

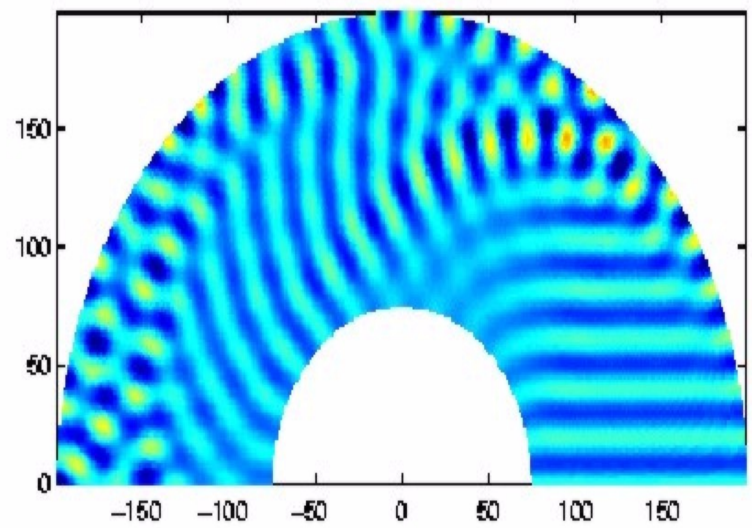
PROBLEM DEFINITION:

- Existing models used by the Corps of Engineers and the civilian sector mostly assume shorelines, yet most realistic shorelines have a variety of features including inlets, emb and harbors
- The model being developed -an extended Boussinesq model that is the most sophistic model for wave problems - will include wave breaking, nonlinear effects, refraction, diff

APROACH:

- Derive the extended Boussinesq equations in a generalized coordinate system, including both orthogonal and non-orthogonal grid applications
- Develop a numerical code for these equat based on the high-order schemes presently used in Cartesian grid applications
- Develop a pre-processor to generate coor grids for realistic coastlines
- Test the model against available data sets

Wave propagation in a curved channe



ACCOMPLISHMENTS:

- Extended Boussinesq equations in generalized coordinate system, including fully nonlinear effects and enhanced frequency dispersion, have been derived
- Successful testing of simple curvilinear geometries

PAYOFF:

- A new computational tool for the DC (Army & Navy) to predict wave and wave-induced current motions in complex coastal environments

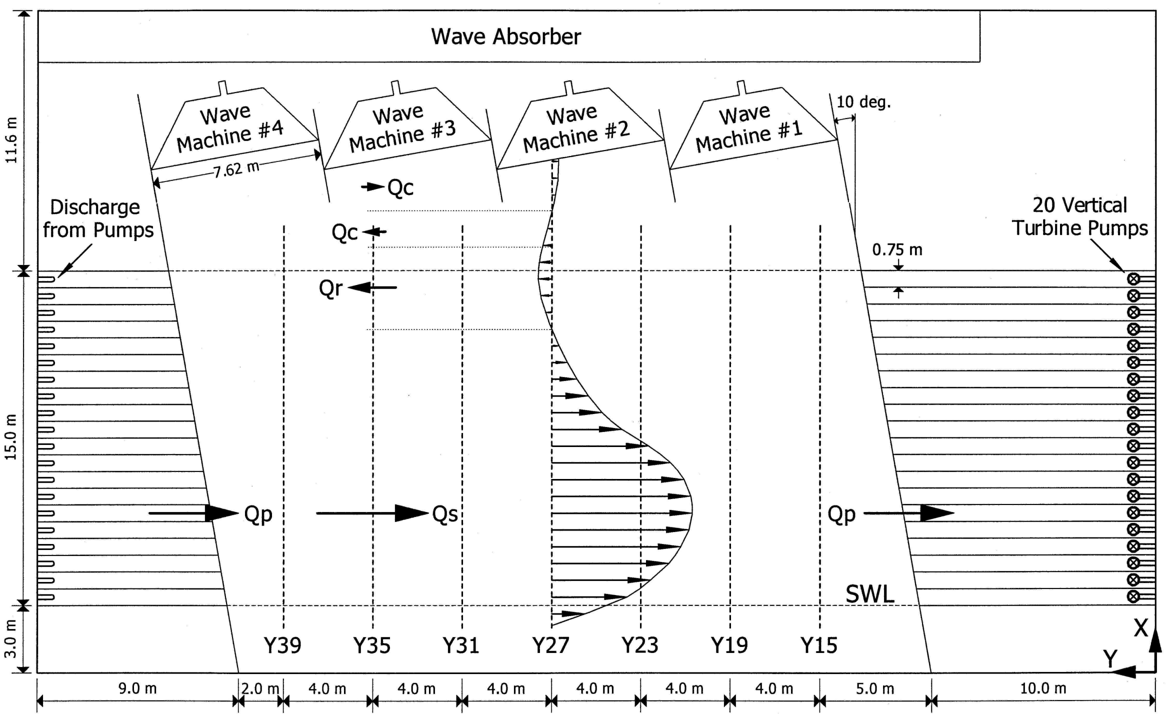
Computational Model for the Hydrodynamics a… Littoral Processes at the COE-ERDC LSTF

PERFORMER:

- Prof. Ib Svendsen (University of Delaware)

OBJECTIVE:

- To simulate flows and sediment motions in the COE-ERDC Large-Scale Sediment Transport Facility (LSTF)

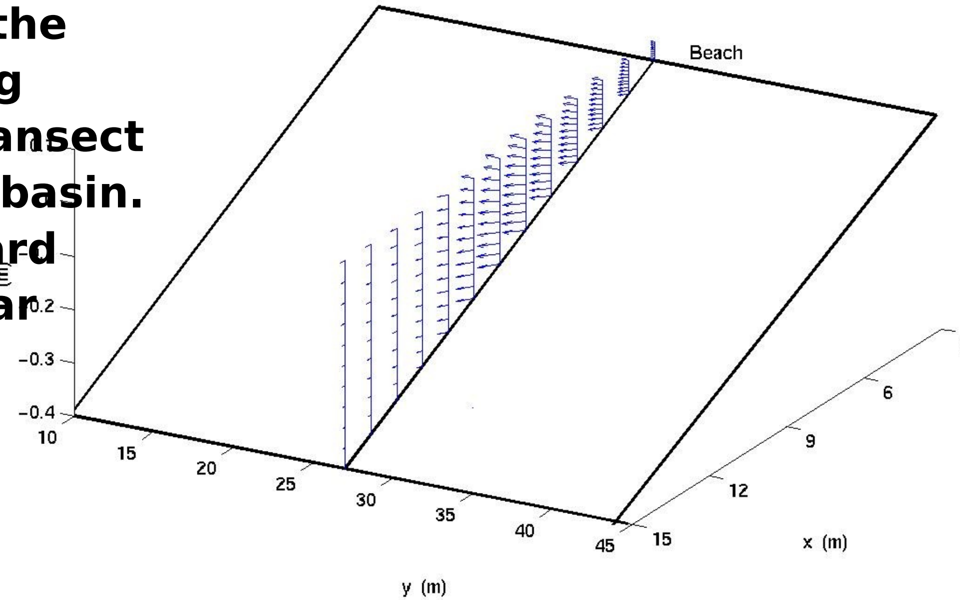


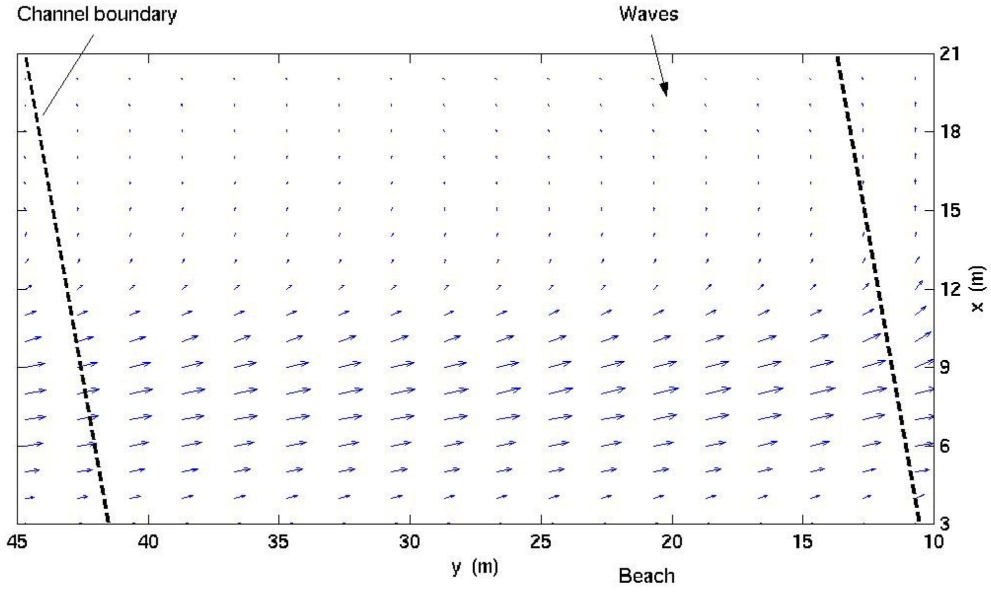
Layout of the LSTF.
The four wave makers generate large-scale waves moving towa… and breaking on the beach at t… bottom of the figure. In the processes, strong longshore currents are generated.

APPROACH:

- Extensive measurements of waves and currents form the basis for the model compari…

RIGHT: Computed 3-D profiles of the horizontal current velocities along the inner part of a cross-shore transect of the beach in the middle of the basin. The currents are twisted shoreward near the surface and seaward near the bottom due to the undertow.





LEFT: Computed distribution o
wave generated current veloci
in the basin at mid-depth. The
distribution is nearly longshor
uniform as desired. The slight
offshore direction of the veloc
vectors is due to the undertow
which is strongest near mid-de
of the water column.

FUTURE RESEARCH DIRECTIONS

Decadal Outline for Military Nearshore Environment Research

Discussion paper from the

Coastal Processes and Dynamics Workshop

held at

USACE Engineer Research and Development Center
Coastal and Hydraulics Laboratory, Field Research Facility

Duck, NC
22-23 January 2001

Nearshore Processes Research

FUTURE RESEARCH DIRECTIONS

A Nearshore Prediction System For Short-Term (<Month) Dynamic B

- **Requires:** - Initial conditions
  - Forcing conditions
  - Observations (past or present from area of interest or a similar area)
  - Verification/assimilation (indicators of model performance)

- **Predicts:** - Important Characteristics (e.g. for the surf zone, width, bar positio
  - Initial Conditions:
  - Bathymetry (resolution 1 m horizontal), Geologic Framework (1m horizontal r
    vertical TBD), Sediment Characteristics, Bedforms/Roughness, Water Te
    and Salinity, Suspended Sediments
  - Forcing Conditions:
    Winds, Offshore Directional Wave Spectra, Tidal/Ambient Currents, Inlow
    Observations:
    Currents, Waves, Bathymetry
- **Other:**
  - Quantify skill in model results, and sensitivity to model input
  - Reconnaissance capability for local geologic framework (of special concern ar
    model should adapt to a different framework)
  - Directional Wave Input (temporally varying wave groups)
  - Determine Model Sensitivity (importance of the variability of each paramete

Nearshore Processes Research

FUTURE RESEARCH DIRECTIONS

Operational Requirements for the

earshore Prediction System For Short-Term Dynamic Bathyme

Predictions must be:

- **relocatable globally**
- **accurate to a defined level of confidence**
- **timely**
- **substantive (i.e. complete in terms of describing potential sm**
- **or short-term temporal variations)**
- **integrated to work with other modeling systems (including da processing, and disseminating systems)**

Areas of Research Focus:

- **model development**
- **observation and remote sensing**
- **coastal processes**